Fermentation of the Yugoslavian Pickled Cabbage[1]

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ABSTRACT

PEDERSON, CARL S. (Cornell University, Geneva, N. Y.), GORDANA NIKETIĆ, AND MARGARET N. ALBURY. Fermentation of the Yugoslavian pickled cabbage. Appl. Microbiol. **10**:86-89. 1962.—In Yugoslavia, cabbage is preserved by fermentation using a variety of methods. Bacteriological study of these fermentations has shown that the relative influence of the various lactic acid producing bacteria varies somewhat with the method of preservation. The heterofermenters, *Leuconostoc mesenteroides* and *Lactobacillus brevis*, exert a greater effect when cabbage is shredded than when the whole heads are packed in salt brine. Whole heads of cabbage preserved by fermentation in salt brine are a good source of ascorbic acid and provide a flavorful food.

Cabbage is a vegetable of prime importance in the Yugoslav diet because of the frequency of its use and because it is the chief natural source of vitamin C. In season it is used as a fresh vegetable and at other times as the fermented product, "Kiseo Kupus." The fermented product may be prepared in Yugoslavia by one of three general methods: by fermenting whole heads in salt brine, by fermenting shredded cabbage packed with dry salt, or by fermenting a combination of whole heads and shredded cabbage with salt.

Our interest concerned the fermentation of the whole heads in salt brine. In Yugoslavia, particularly in the republic of Serbia, whole heads of white or red cabbage are packed in salt brine. Although sometimes the cabbage cores are scored crosswise before packing the heads in brine, more often the heads are packed with no alteration of the cores.

The fermented product is used in several ways. "Sarma" is usually made by baking ground meat rolled within the fermented leaves. "Podvarak" is prepared by baking slices of fermented cabbage with turkey, goose, or pork, or by baking fowls which have been stuffed with a kraut dressing. The fermented whole cabbage also is served cold as a salad or cooked in chunks or slices with pork. Brine from the red kraut, "Raso," has a pink wine color and is relished as an appetizer.

Since there is so little standardization of methods of manufacture, it was desirable to learn more about the effects of varying concentrations of salt brine on the fermentation of whole heads of cabbage.

MATERIALS AND METHODS

In 1958, 1959, and 1960 a total of six barrels of cabbage were packed by one of the three methods used in Yugoslavia. Most of the cabbage was obtained from a local sauerkraut factory. It was packed into the barrels as tightly as possible and brought to the laboratory. Stainless steel tubes were inserted to the center of each barrel during the packing to facilitate removal of samples of brine for analysis. When the cabbage had wilted slightly, the wooden barrel covers were wedged below the surfaces of the brines to force the heads of shredded cabbage well below the brine surface. To inhibit surface yeast growth, polyethylene plastic covers were placed on the brine surfaces and weighted with water. Brine temperature averaged approximately 20 C and ranged from 15 to 25 C.

At regular intervals during fermentation, samples of brines were withdrawn for bacteriological and chemical analyses. Platings were prepared at desired dilutions using an agar containing 0.5% Tryptone, 2.0% glucose, 0.25% yeast extract, and 2.0% agar. Plates were incubated at 32 C for 2 to 3 days. After colonies on the plates were counted, representative colonies were selected for isolation and for identification as described by Pederson and Albury (1954). Total acid, pH, salt, and total solids were determined by titration, use of a pH meter, and a refractometer. Ascorbic acid was determined by the method of Robinson and Stotz (1945).

In 1958, three barrels of whole cabbage heads were packed in brines of 1.25, 2.25, and 3.5% salt calculated from the combined weight of brine and cabbage. The cabbage was obtained from the trimming line after the heads had been cored and trimmed. The brines were prepared immediately before they were added to the cabbage. In addition, one barrel of conventionally shredded cabbage was packed with 2.25% dry salt as a control.

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In 1959, one barrel of whole, uncored cabbage was packed with 3.5% salt brine. Analyses made in 1958 were similar except for the omission of ascorbic acid and total solids determinations. In 1960, one barrel was packed with a mixture of whole uncored and shredded cabbage. Heads of a small solid miniature variety of cabbage were also placed among the shreds. Dry salt of 3.14% was added. This barrel of shredded cabbage and heads of cabbage was placed in a fermentation room where a constant temperature of 21 C was maintained.

Results and Discussion

The fermentations of whole cabbages in brines in 1958 were distinctive for their slower rates of fermentation and more limited production of acid compared to shredded cabbage fermentation. Salt absorption by the vegetable occurred more gradually than when shredded cabbage ferments. The pattern of salt changes was similar to that of fermenting cucumbers in brine. Noteworthy was the observation that ascorbic acid values for the brines showed a gradual increase with

TABLE 1. *Development of acid and change in bacterial flora in brine of whole head cabbage, 1958*

Analysis of brines					Estimated no. of each type (10^5 per ml)						
Time	Ascorbic acid	Salt	Acid	pH	Total plate count	Aerobic species	*Leuconostoc mesenteroides*	*Lactobacillus brevis*	*Pediococcus cereviseae*	*Lactobacillus plantarum*	Yeast
hr	*mg/100g*	%	%								
No. 1. Barrel containing 1.25% salt											
5	—	—	0.01	6.26	4.2	3	0.2				1
23	—	2.4	0.04	5.48	266*	126	46				
28	—	2.4	0.05	4.82	1,000*	210	210	50			
45	2.9	2.3	0.12	4.02	660	370	83				
52	5.8	—	0.14	3.92	1,070	404	666				
69	8.6	3.0	0.23	3.80	920	306	358			204	50
76	9.0	1.8	0.24	—	750		630		40	80	
93	9.8	1.8	0.35	3.60	840		760			40	40
100		1.8	0.38	3.60	530	26	425		26	53	
days											
5	11.3	1.8	0.46	3.52	1,120		900	60		160	
6	11.6	1.7	0.52	3.50	1,600		640	80		880	
7		1.7	0.61	3.50	2,830		176	540	176	1,590	350
8	12.7	1.6	0.67	3.45	1,710					1,620	90
9	13.2	1.6	0.73	3.45	1,860			190		1,490	180
12	13.2	1.6	0.85	3.33	1,400					1,400	
14	14.2	1.5	0.91	3.38	1,270			60		1,210	
21	17.0	1.4	1.10	3.38	760					680	80
25	17.0	1.3	1.15	3.38	450					450	
31	18.0	1.2	1.20	3.35	250					240	10
No. 3. Barrel containing 3.5% salt											
hr											
5	—	6.0	0.01	6.30	2	1.5				0.3	0.2
23	—	5.4	0.04	5.58	4	2.7	0.7			0.6	
28	—	5.2	0.04	5.43	5	2	2				1
45	1.0	4.9	0.04	5.22	220		200		20		
52	1.9		0.04	5.20	340	50	222		34	34	
69	3.8	4.6	0.09	4.10	380	20	220		120	20	
76	5.3	4.3	0.12	—	925	231	462		184	46	
93	7.6	4.3	0.19	3.75	370	—	203		167	14	
100	—	4.3	0.21	3.70	290		174	15	84	—	
days											
5	10.4	4.3	0.28	3.64	340		187	34	102	17	
6	11.7	4.2	0.39	3.52	440		22	264		154	
7	12.8	4.1	0.45	3.48	390	52		182		156	
8	14.9	4.1	0.53	3.50	420			105	21	273	21
9	15.6	4.0	0.60	3.40	270			27		243	
12	16.1	3.9	0.70	3.30	160			92		60	8
14	17.4	3.8	0.79	3.32	140			28		112	
21	21.2	3.7	0.95	3.36	30			2		24	
25	21.7	3.6	0.97	3.38	23			1		22	4
31	22.4	3.5	1.07	3.35	8			—	0.8	6.8	0.4

* Estimated number of *Streptococcus* sp.: 94×10^5 and 530×10^5.

the outward diffusion of that vitamin from the cabbage (Table 1). The ascorbic acid values of the brines, however, never equaled the ascorbic acid levels of the brines of shredded cabbage kraut. Salt concentrations became equilibrated between brine and vegetable after 3 to 4 weeks. Although pH changes were similar in all three salt concentrations, the earliest marked increase in total acidity occurred in the brine of lowest salinity.

Bacterial populations differed for the three salinities (Table 1). The most rapid increase in numbers occurred in the brine of lowest salt concentration, 1.25%, as shown by a count of 2,830 × 10^5 per ml on the seventh day. At this time, the greatest variation in flora was observed. In the 2.25 and 3.5% brines, maximal counts were 450 × 10^5 and 920 × 10^5 at 2 and 3 days, respectively (Table 1). Again, the greatest variation in flora was noted when the counts were highest. In each fermentation, early stages were dominated by the heterofermenting *Leuconostoc mesenteroides* species. Although strains of the heterofermenter *Lactobacillus brevis* were also isolated from all three barrels, the homofermenting lactic species showed greater activity than is characteristic of shredded kraut fermentations. For example, in the higher concentration brines greater numbers of strains of *Pediococcus cerevisiae* were observed. The relative effect of the homofermenting lactic species is correlative with the low acetic acid to lactic acid ratios of the final brines, i.e., 0.116, 0.096, and

TABLE 2. *Development of acid and change in bacterial flora in brine of whole head cabbage, 1959 and shredded and whole head of cabbage, 1960*

Time	Analysis of brines			Estimated no. of each type (10^5 per ml)						
	Salt	Acid	Brine pH	Total plate count	Aerobic species	*Leuconostoc mesenteroides*	*Lactobacillus brevis*	*Pediococcus cerevisiae*	*Lactobacillus plantarum*	Yeasts
days	%	%								
No. 4. 1959. Whole heads of cabbage in 3.5% salt										
⅛	—	—	—	34	34					
1	5.3	0.01	6.22	0.33	0.33					
2	5.3	0.01	5.27	0.80	0.80					
3	5.3	0.01	5.29	4.3	4.3					
4	4.9	0.02	5.27	9.5	9.5					
5	4.7	0.02	5.12	17	14			3		
7	4.6	0.03	5.48	50	37	8		5		
9	4.2	0.03	5.53	119	41	36			42	
10	4.2	0.06	4.47	186		28	9		149	
11	4.2	0.13	3.72	389			117		272	
12	4.0	0.23	3.62	600			90		510	
14	3.9	0.30	3.55	770					770	
16	3.8	0.41	3.47	725	35				690	
18	3.8	0.40	3.58	620			30		590	
21	3.8	0.48	3.47	575			29	29	517	
25	3.9	0.51	3.40	336					336	
29	3.9	0.48	3.56	231		12			219	
35	3.9	0.58	3.38	147					147	
50	4.0	0.81	3.39	14					12	2
67	3.8	0.87	3.37	36	4		4	21	7	
No. 5. 1960. Mixed shredded and whole heads of cabbage in 3.25% salt										
⅙	4.1	0.06	5.92	5.8	0.5	5.0			0.3	
1	3.9	0.09	5.47	27.4		24.6			1.4	
2	4.0	0.20	4.56	440		440				
3	3.8	0.40	4.22	467		420	47			
4	3.6	0.64	3.99	695*		380	105		174	
5	3.6	0.81	3.77	466		70	93		303	
7	3.5	0.86	3.72	1460			438		949	73
9	3.5	1.11	3.48	306			61		230	15
15	3.5	1.31	3.48	70	4		4		62	
18	3.5	1.33	3.51	52			3		47	2
21	3.4	1.36	3.47	35	2				33	
29	3.3	1.46	3.47	11					11	
36	3.3	1.49	3.45	4					4	
45	3.3	1.58	3.42	8	5	1	1			1
63	3.3	1.58	3.42	4			1		2	1
199	3.2	1.92	3.59	—						

* Estimated number of *Streptococcus* sp.: 35 × 10^5.

0.121 for brines of 1.25, 2.25, and 3.5%, respectively. Total acidities attained were low, i.e., 1.29, 1.19, and 1.22% for the 1.25, 2.25, and 3.5% brines, respectively. Of particular interest in the fermentation in the lowest salt concentration brine was the growth and persistence of aerobic species. A maximal count of 400×10^6 was attained after 52 hr. This growth may have been partially responsible for the softening which prevailed in the fermented product of this barrel.

The fermented whole cabbages exhibited a softening of the core areas which was detrimental to their appearance. Cabbages from the lowest salinity brine showed a softening of the entire heads which made them too soft to be appetizing. Despite visible softening of the cores of cabbages from the 2.25% brine, they were more satisfactory. Those from the 3.5% brine showed only slightly soft cores and their leaves were firm and flavorful. The flavor of the 3.5% brined cabbages was distinctive for its enjoyable blend of taste and mellowness. When used to prepare the Yugoslav dish, "Sarma," an extremely pleasant flavor combination was noted in the association of kraut and meat.

In 1959, uncored heads of cabbage fermented in 3.5% brine produced a somewhat retarded fermentation with final acidity of only 0.87% (Table 2). From a comparison of numbers of each species isolated, it is evident that *Lactobacillus plantarum* was the predominant type. The acetic acid to lactic acid ratio of 0.150 again illustrates the predominating homofermentation. Brine plated on the seventh day of fermentation showed a bacterial count of 50×10^5 per ml in contrast to the count of 39×10^5 for equal salinity brine of cored cabbage of the previous year on the same day. The maximal count was attained on the 14th day, 770×10^5. With delay in the growth of lactic bacteria early in fermentation in 1959, the aerobic species of bacteria for a time exhibited greater activity than usual. Since the original brine count of 34×10^5 was reduced to 0.33×10^5 during the first day, it may be assumed that many aerobic types died and that the increased activity exhibited later resulted from growth of only a few species of the original aerobic bacteria that survived.

The quality of the 1959 uncored whole cabbage kraut was better than that of the cored cabbage kraut of 1958. Flavor and consistency were acceptable and were judged by a former native of Yugoslavia to be far superior to that of the 1958 whole cabbage kraut. Again there was noted a delectable, mellow blend of flavor.

The 1960 barrel containing whole uncored heads of cabbage and of a new miniature variety of cabbage packed with sliced cabbage produced a fermentation similar in activity to typical sliced cabbage kraut, with final total acidity of 1.92% for the brine and 2.14% for the brine contained within the whole heads. Very few strains of aerobic species were isolated. Although a transitory growth of the homofermenting species, *Streptococcus faecalis* and *P. cerevisiae* was observed, growth of strains of the heterofermenters and of the homofermenting *L. plantarum* species accounted for most of the change. The relative activity of the heterofermentative lactic acid strains is reflected by the acetic acid to lactic acid ratios of 0.231 for the brine and 0.324 for the brine within heads. Bacterial population was highest on the seventh day, $1{,}460 \times 10^5$ per ml. The combination of large and miniature heads and the shredded cabbage after fermentation was completely cured.

Discussion

Comparison of 1958 and 1959 kraut with that of 1960 at 3.5% salinity emphasizes the conclusion that growth of the lactic acid species, changes in flora, and acid production occur more rapidly in a fermentation which contains shredded cabbage. The exposure of plant tissues resulting from cutting whole cabbage makes the plant sugars and other nutrients readily available to the bacteria. The unique mellowness of flavor, however, which was apparent in 1958 and 1959 whole cabbage kraut was modified in the kraut where shredded cabbage was present. Instead, a more pungent, acid effect prevailed, possibly because of the increased acidity and particularly the higher volatile to nonvolatile acid ratio.

Whole heads of cabbage in salt brine fermented more slowly and produced less acid than fermentation of shredded cabbage. Also, the homofermentative lactic acid bacteria exerted a proportionately greater effect upon the total changes of the whole head cabbage fermentation than normally occurs in shredded kraut fermentation.

A brine equivalent to 3 to 3.5% salt is necessary for retention of good texture. The leaves of the heads are distinctly palatable for their unique, mellow flavor, and they and their brine provide a good source of ascorbic acid.

LITERATURE CITED

Pederson, C. S., and M. N. Albury. 1954. The influence of salt and temperature on the microflora of sauerkraut fermentation. Food Technol. **8**:1–5.

Robinson, W. B., and E. Stotz. 1945. The indophenol xylene extraction method for ascorbic acid and modifications for interfering substances. J. Biol. Chem. **160**:217–225.